Visual Perception

CS 7450 - Information Visualization
November 18, 2015
John Stasko

Agenda

- Visual perception
  - Pre-attentive processing
  - Color
  - Etc.
Semiotics

- The study of symbols and how they convey meaning

- Classic book:

Related Disciplines

- Psychophysics
  - Applying methods of physics to measuring human perceptual systems
    - How fast must light flicker until we perceive it as constant?
    - What change in brightness can we perceive?

- Cognitive psychology
  - Understanding how people think, here, how it relates to perception
Perceptual Processing

- Seek to better understand visual perception and visual information processing
  - Multiple theories or models exist
  - Need to understand physiology and cognitive psychology

One (simple) Model

- Two stage process
  - Parallel extraction of low-level properties of scene
  - Sequential goal-directed processing

Stage 1
- Early, parallel detection of color, texture, shape, spatial attributes

Stage 2
- Serial processing of object identification (using memory) and spatial layout, action

Ware 2000
Stage 1 - Low-level, Parallel

- Neurons in eye & brain responsible for different kinds of information
  - Orientation, color, texture, movement, etc.
- Arrays of neurons work in parallel
- Occurs “automatically”
- Rapid
- Information is transitory, briefly held in iconic store
- Bottom-up data-driven model of processing
- Often called “pre-attentive” processing

Stage 2 - Sequential, Goal-Directed

- Splits into subsystems for object recognition and for interacting with environment
- Increasing evidence supports independence of systems for symbolic object manipulation and for locomotion & action
- First subsystem then interfaces to verbal linguistic portion of brain, second interfaces to motor systems that control muscle movements
Stage 2 Attributes

- Slow serial processing
- Involves working and long-term memory
- More emphasis on arbitrary aspects of symbols
- Top-down processing

Preattentive Processing

- How does human visual system analyze images?
  - Some things seem to be done preattentively, without the need for focused attention
  - Generally less than 200-250 msecs (eye movements take 200 msecs)
  - Seems to be done in parallel by low-level vision system

Drawn from C. Healey web article
How Many 3’s?

1281768756138976546984506985604982826762
9809858458224509856458945098450980943585
909103209905959595772564675050678904567
8845789809821677654876364908560912949686
What Kinds of Tasks?

- Target detection
  - Is something there?
- Boundary detection
  - Can the elements be grouped?
- Counting
  - How many elements of a certain type are present?

Example

- Determine if a red circle is present
- (2 sides of the room)
Hue

Can be done rapidly (preattentively) by people
Surrounding objects called “distractors”

Example

- Determine if a red circle is present
Shape

Can be done preattentively by people

Example

- Determine if a red circle is present
Hue and Shape

- Cannot be done preattentively
- Must perform a sequential search
- Conjunction of features (shape and hue) causes it

Example

- Is there a boundary in the display?
Fill and Shape

- Left can be done preattentively since each group contains one unique feature
- Right cannot (there is a boundary!) since the two features are mixed (fill and shape)

Example

- Is there a boundary in the display?
Hue versus Shape

Left: Boundary detected preattentively based on hue regardless of shape
Right: Cannot do mixed color shapes preattentively

Example

- Is there a boundary?
Hue versus brightness

Left: Varying brightness seems to interfere
Right: Boundary based on brightness can be done preattentively

Example Applet

• Nice on-line tutorial and example applet
  – http://www.csc.ncsu.edu/faculty/healey/FP/index.html
  – Chris Healey, NC State
  – Prior pictures taken from site
Preattentive Features

- Certain visual forms lend themselves to preattentive processing
- Variety of forms seem to work

3-D Figures

3-D visual reality has an influence
Emergent Features

Potential PA Features

- length
- width
- size
- curvature
- number
- terminators
- intersection
- closure
- hue
- intensity
- flicker
- direction of motion
- binocular lustre
- stereoscopic depth
- 3-D depth cues
- lighting direction
Discussion

- What role does/should preattentive processing play in information visualization?

Gestalt Laws

- Background
  - German psychologists, early 1900’s
  - Attempt to understand pattern perception
  - Founded Gestalt school of psychology
  - Provided clear descriptions of many basic perceptual phenomena
    - Gestalt Laws of Pattern Perception
Gestalt Laws

- Proximity
  - Things close together are perceptually grouped together
- Similarity
  - Similar elements get grouped together
- Connectedness
  - Connecting different objects by lines unifies them
- Continuity
  - More likely to construct visual entities out of smooth, continuous visual elements

Gestalt Laws

- Symmetry
  - Symmetrical patterns are perceived more as a whole
- Closure
  - A closed contour is seen as an object
- Relative Size
  - Smaller components of a pattern as perceived as objects
- Figure & Ground
  - Figure is foreground, ground is behind
Key Perceptual Properties

- Brightness
- Color
- Texture
- Shape

Luminance/Brightness

- Luminance
  - Measured amount of light coming from some place
- Brightness
  - Perceived amount of light coming from source
Brightness

- Perceived brightness is non-linear function of amount of light emitted by source
  - Typically a power function
  
  \[ S = aI^n \]
  
  - Sensation
  - Intensity

- Very different on screen versus paper

Grayscale

- Probably not best way to encode data because of contrast issues
  - Surface orientation and surroundings matter a great deal
  - Luminance channel of visual system is so fundamental to so much of perception
    
    We can get by without color discrimination, but not luminance
Color

- Sensory response to electromagnetic radiation in the spectrum between wavelengths 0.4 - 0.7 micrometers

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Color Models

- HVS model
  - Hue - what people think of color
  - Value - light/dark, ranges black $\rightarrow$ white
  - Saturation - intensity, ranges hue $\rightarrow$ gray
How Not to Use Color

Color Categories

- Are there certain canonical colors?
  - Post & Greene ‘86 had people name different colors on a monitor
  - Pictured are ones with > 75% commonality


From Ware ‘04
Maybe Not All the Same?


Himba tribe

Article Discussion

http://www.b-eye-network.com/newsletters/ben/2235

Your thoughts?
Luminance

• Important for fg-bg colors to differ in brightness

Color for Categories

• Can different colors be used for categorical variables?
  – Yes (with care)
  – Ware’s suggestion: 12 colors
    red, green, yellow, blue, black, white, pink, cyan, gray, orange, brown, purple

From Ware ‘04
Color for Sequences

Can you order these (low->hi)

Possible Color Sequences

Gray scale  Full spectral scale  Single sequence part spectral scale  Single sequence single hue scale  Double-ended multiple hue scale
Advice

Don’t use the rainbow color scale for quantitative data

ColorBrewer

Help with selecting colors for maps

http://colorbrewer2.org/
Color Purposes

- Call attention to specific data
- Increase appeal, memorability
- Increase number of dimensions for encoding data
  - Example, Ware and Beatty '88
    - $x,y$ - variables 1 & 2
    - amount of $r,g,b$ - variables 3, 4, & 5

Using Color

- Modesty!  Less is more
- Use blue in large regions, not thin lines
- Use red and green in the center of the field of view (edges of retina not sensitive to these)
- Use black, white, yellow in periphery
- Use adjacent colors that vary in hue & value
Using Color

- For large regions, don’t use highly saturated colors (pastels a good choice)
- Do not use adjacent colors that vary in amount of blue
- Don’t use high saturation, spectrally extreme colors together (causes after images)
- Use color for grouping and search
- Beware effects from adjacent color regions (my old house - example)

Are regions A and B the same color?

https://en.wikipedia.org/wiki/Checker_shadow_illusion
Tableau’s Colors

Provides “default” colors for legend items
Use NLP, Google n-grams & images

Setlur & Stone
TVCG (InfoVis) ’15

More Choices

Fig. 9. Results for Lin’s algorithm (A), expert (E) and our algorithm (G).
Color Challenge

http://color.method.ac/

Test your color abilities

Good Color Advice

Maureen Stone’s website
Many references and links
She frequently offers tutorials about color at conferences

http://www.stonesc.com
Color Resources

Texture

- Appears to be combination of
  - orientation
  - scale
  - contrast

- Complex attribute to analyze
**Shape, Symbol**

- Can you develop a set of unique symbols that can be placed on a display and be rapidly perceived and differentiated?
- Application for maps, military, etc.
- Want to look at different preattentive aspects

**Glyph Construction**

- Suppose that we use two different visual properties to encode two different variables in a discrete data set
  - color, size, shape, lightness
- Will the two different properties interact so that they are more/less difficult to untangle?
  - Integral - two properties are viewed holistically
  - Separable - Judge each dimension independently
Integral-Separable

• Not one or other, but along an axis

<table>
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<th>Separable</th>
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<td>black-white</td>
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<td>direction motion</td>
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<td>x,y position</td>
<td>size, shape, color</td>
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</tbody>
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Ware '04

Encodings

• When you want to communicate one type of variable, which visual property should you use?
### Change Blindness

- Is the viewer able to perceive changes between two scenes?
  - If so, may be distracting
  - Can do things to minimize noticing changes
- Fun examples
  - Static pictures (Ron Rensink, UBC)
  - Videos (Dan Simons, Illinois)
Optical Illusions

Stage 2

- Missing here!
- Object recognition and locomotion/action
- Maybe in the future... :^)
Great Book

Information Visualization
Perception for Design
2nd edition
Colin Ware
Morgan Kaufmann

HW 6 Return

• Plus some other older ones
Project

- Deliverables
  - Demo to Ramik, Iulian & John
    Final exam week, sign up on t-square
  - Video
    5 minutes max, show in final exam period
    Wednesday 9th

Video Advice

- Use Camtasia
- Process
  - 1. Develop script (rehearse timing)
  - 2. Record script
  - 3. Capture video of demo to script
  - 4. Add effects

- You’ve seen examples all semester
Upcoming

• Evaluation
  – Papers
    Carpendale ’08

• Thanksgiving holiday
  – No class

• Review
  – Papers
    *Now You See It*, chapter 13
    Heer et al ‘10

Sources Used

Healey website and article
http://www.csc.ncsu.edu/faculty/healey/PP/index.html

Marti Hearst SIMS 247 lectures
C. Ware, *Information Visualization*